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**Rofougaran**

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(54) **PROBABILITY OPTIMIZED POWER AMPLIFIER MODULE AND TRANSMITTER**

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*H04B 1/04* (2006.01)

(52) **U.S. Cl.** .................... **455/127.1**; 455/323; 455/341; 330/129

(58) **Field of Classification Search** ............. 455/127.1, 455/127.2, 127.3, 323, 334, 341; 330/129, 330/130

See application file for complete search history.

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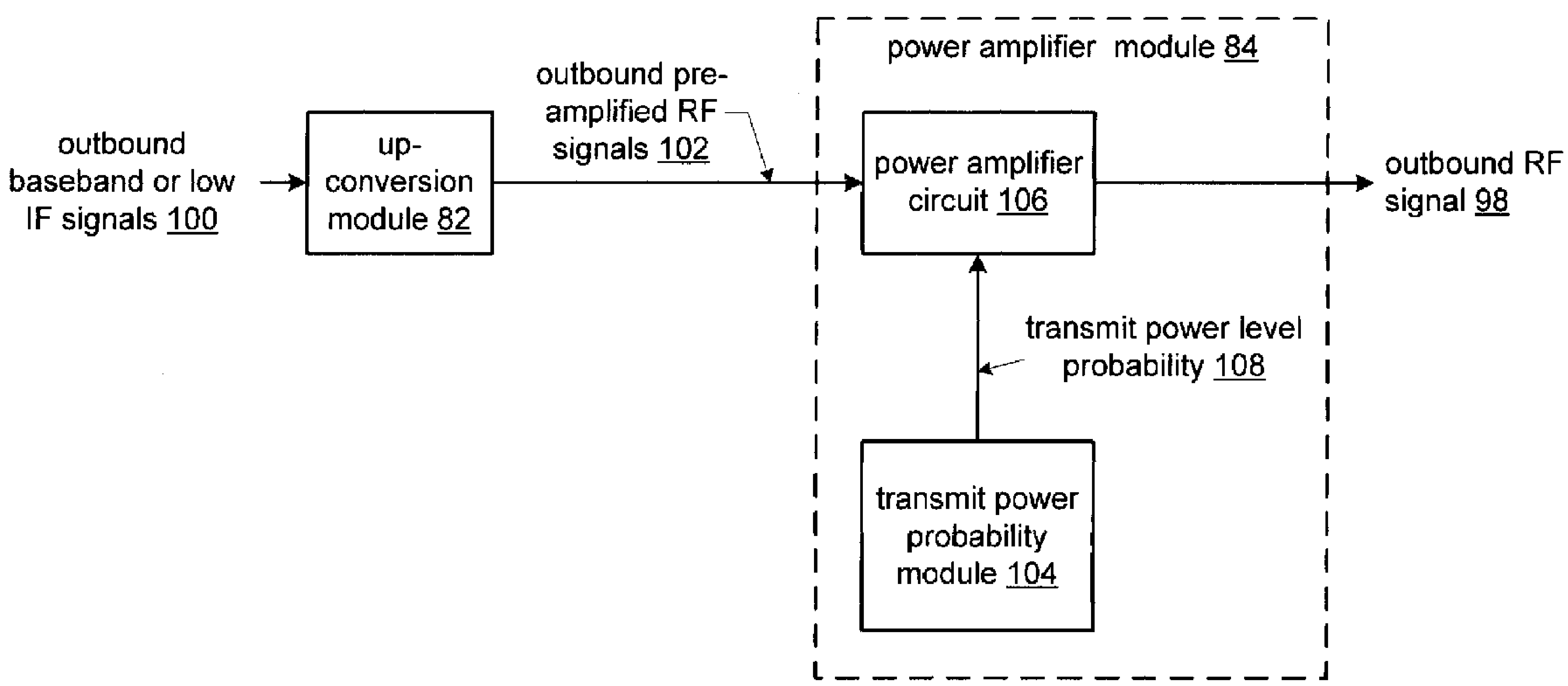
(57) **ABSTRACT**

A power amplifier module includes a transmit power probability module and a power amplifier circuit. The transmit power probability module is coupled to determine a transmit power level probability. The power amplifier circuit is coupled to amplify an outbound radio frequency (RF) signal at a power level in accordance with the transmit power level probability and a desired transmit power level.

**6 Claims, 6 Drawing Sheets**



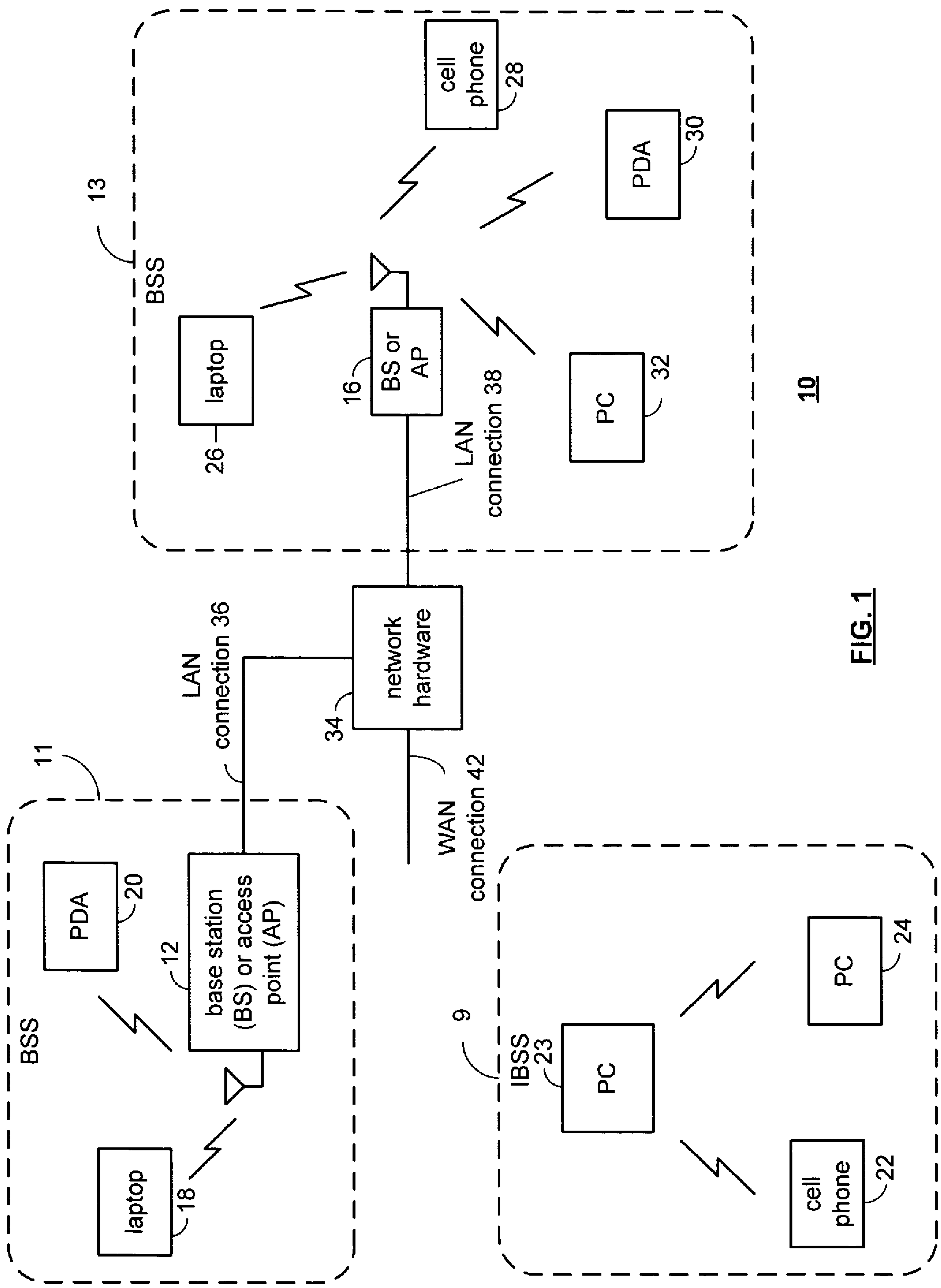

BSS
13
laptop
26
BS or AP
16
cell phone
28
PDA
30
PC
32
LAN connection 38
10
network hardware
34
LAN connection 36
WAN connection 42
11
BSS
PDA
20
base station (BS) or access point (AP)
12
laptop
18
9
IBSS
23
PC
PC
24
cell phone
22

FIG. 1

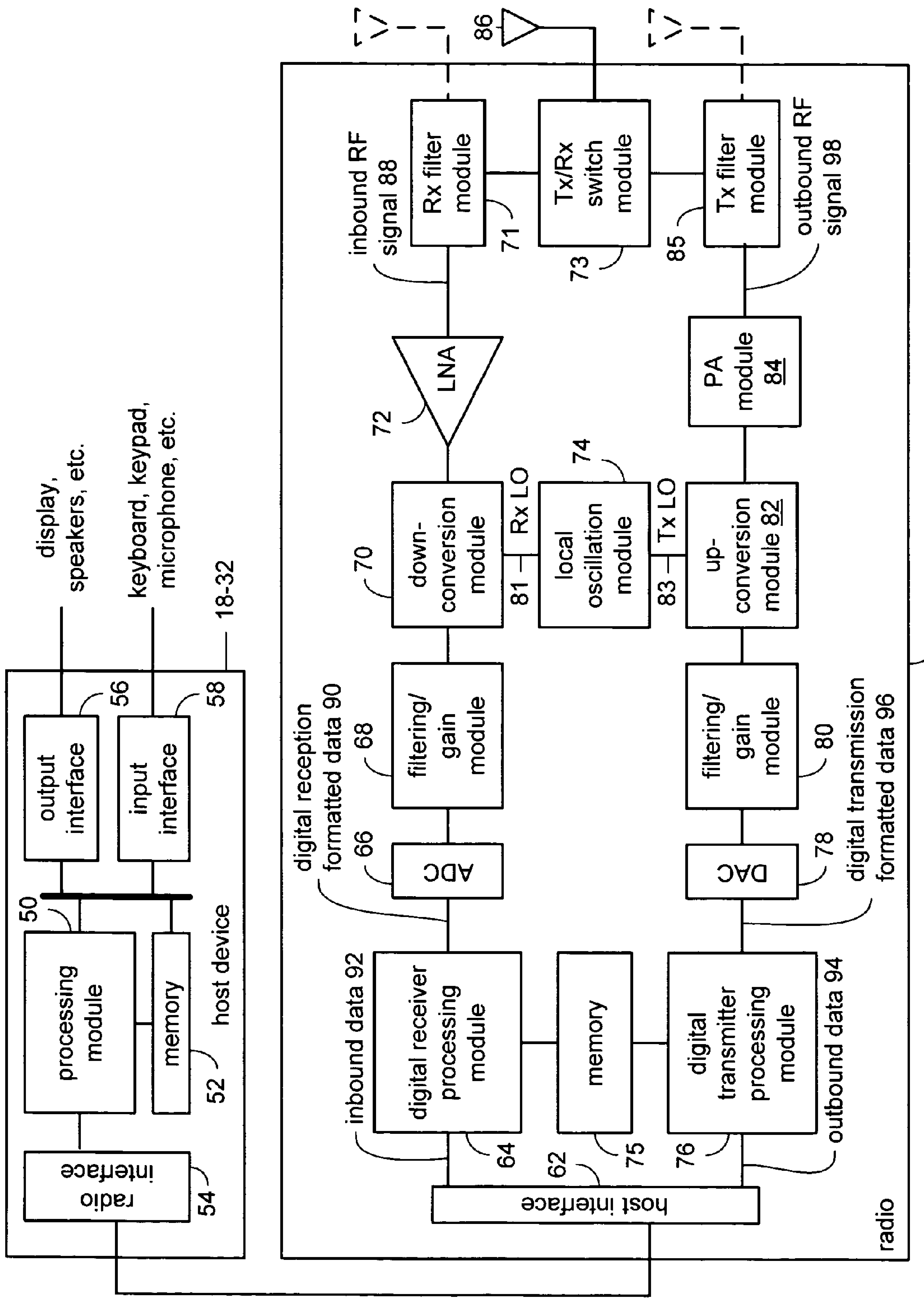

display, speakers, etc.
keyboard, keypad, microphone, etc.
18-32
output interface
56
input interface
58
50
processing module
memory
52
host device
radio interface
54
host interface
62
radio
60
inbound data 92
digital receiver processing module
64
memory
75
digital transmitter processing module
76
outbound data 94
digital reception formatted data 90
ADC
66
filtering/ gain module
68
down- conversion module
70
81
Rx LO
local oscillation module
74
Tx LO
83
up- conversion module 82
filtering/ gain module
80
DAC
78
digital transmission formatted data 96
LNA
72
PA module 84
inbound RF signal 88
Rx filter module
71
Tx/Rx switch module
73
Tx filter module
85
outbound RF signal 98
86

FIG. 2

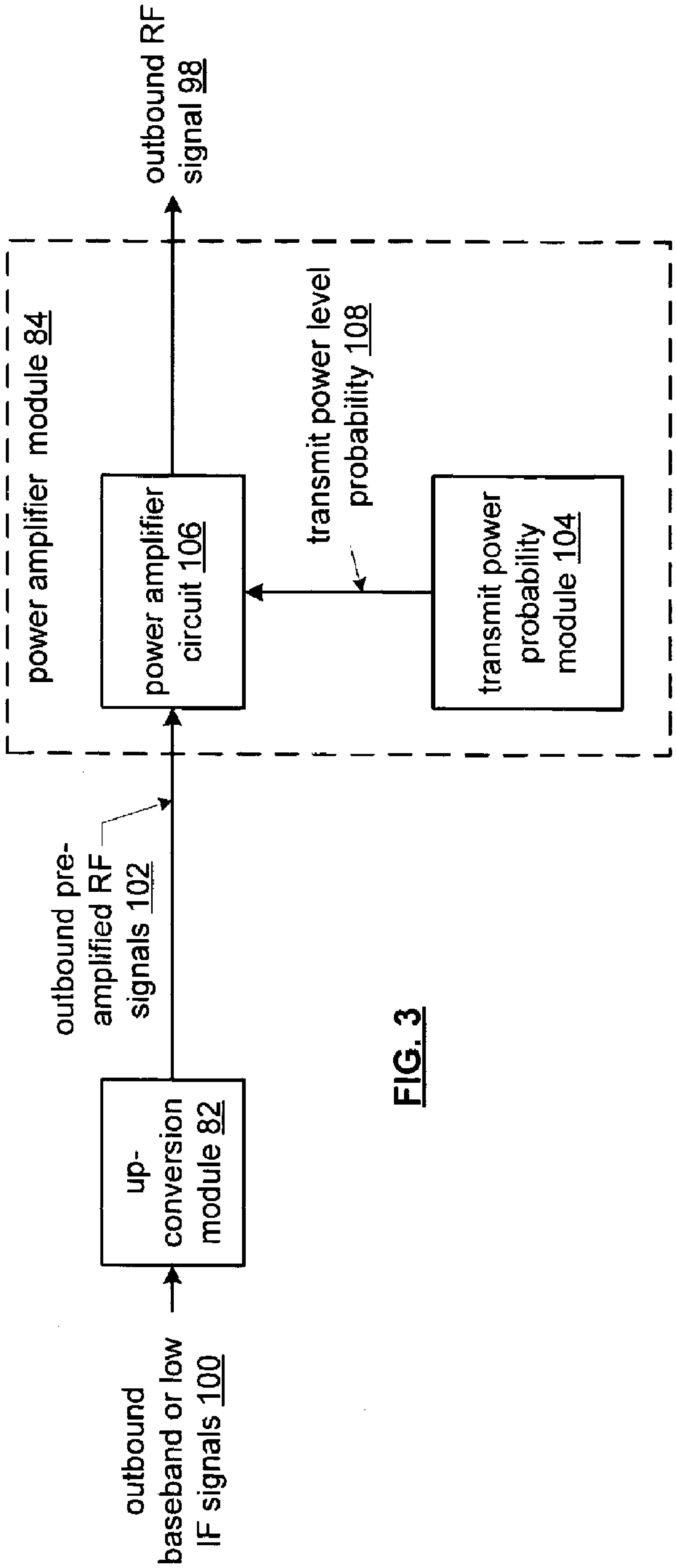

outbound baseband or low IF signals 100
up-conversion module 82
outbound pre-amplified RF signals 102
power amplifier module 84
power amplifier circuit 106
transmit power level probability 108
transmit power probability module 104
outbound RF signal 98

FIG. 3

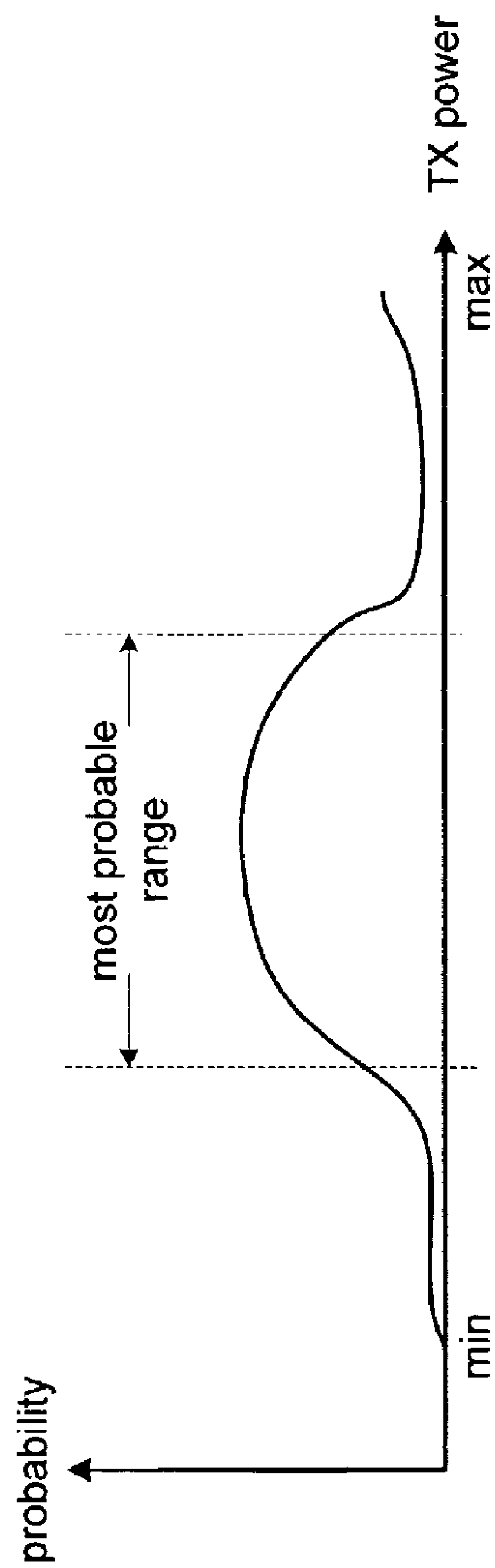

probability
most probable range
min
max
TX power

FIG. 4

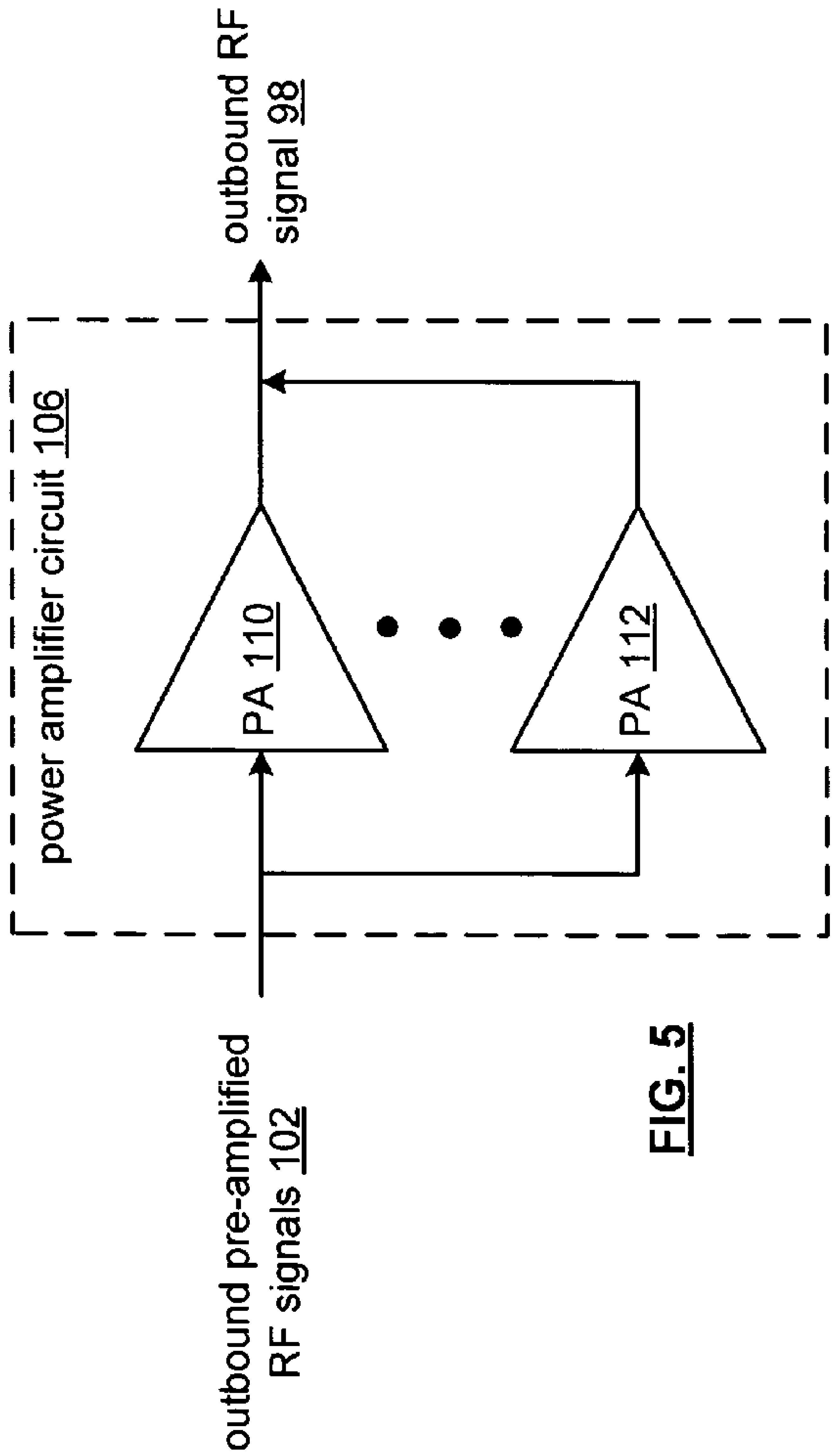



FIG. 5

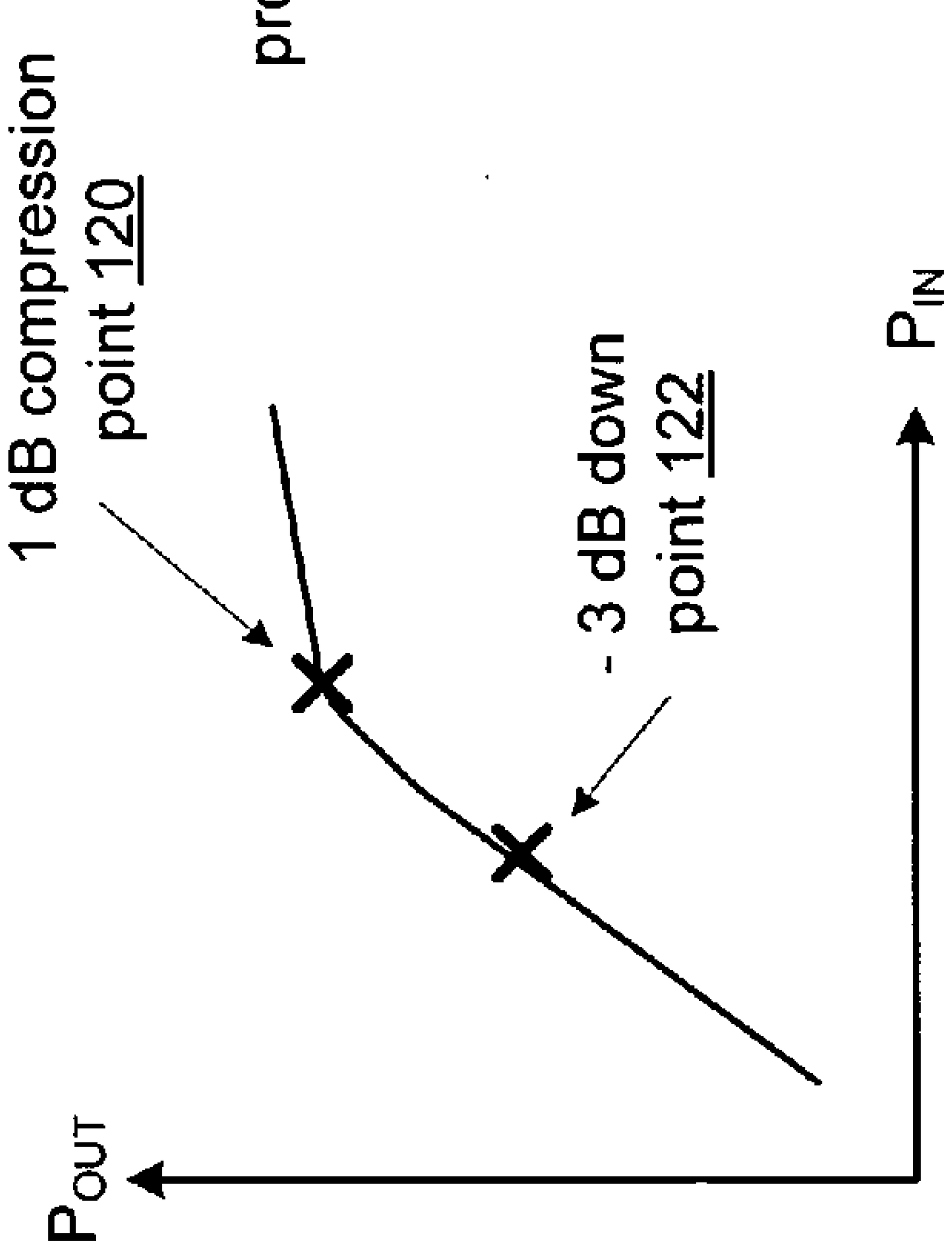



FIG. 6

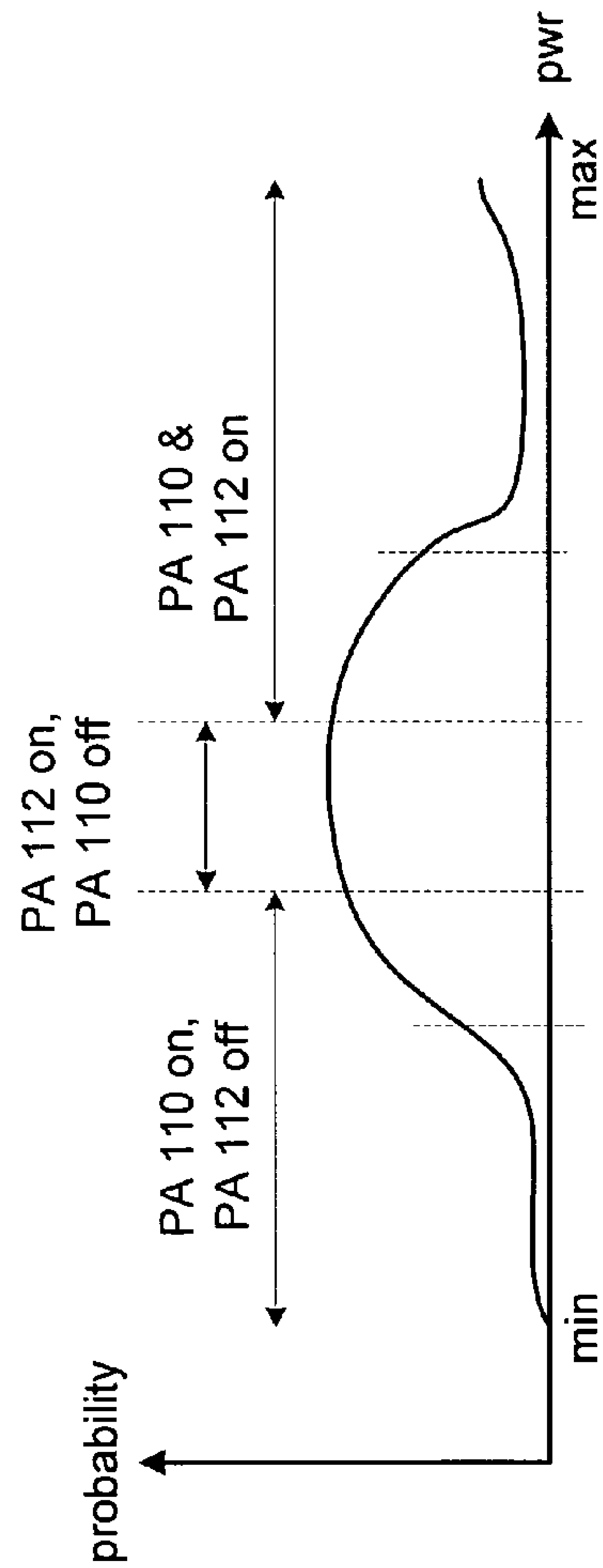



FIG. 7

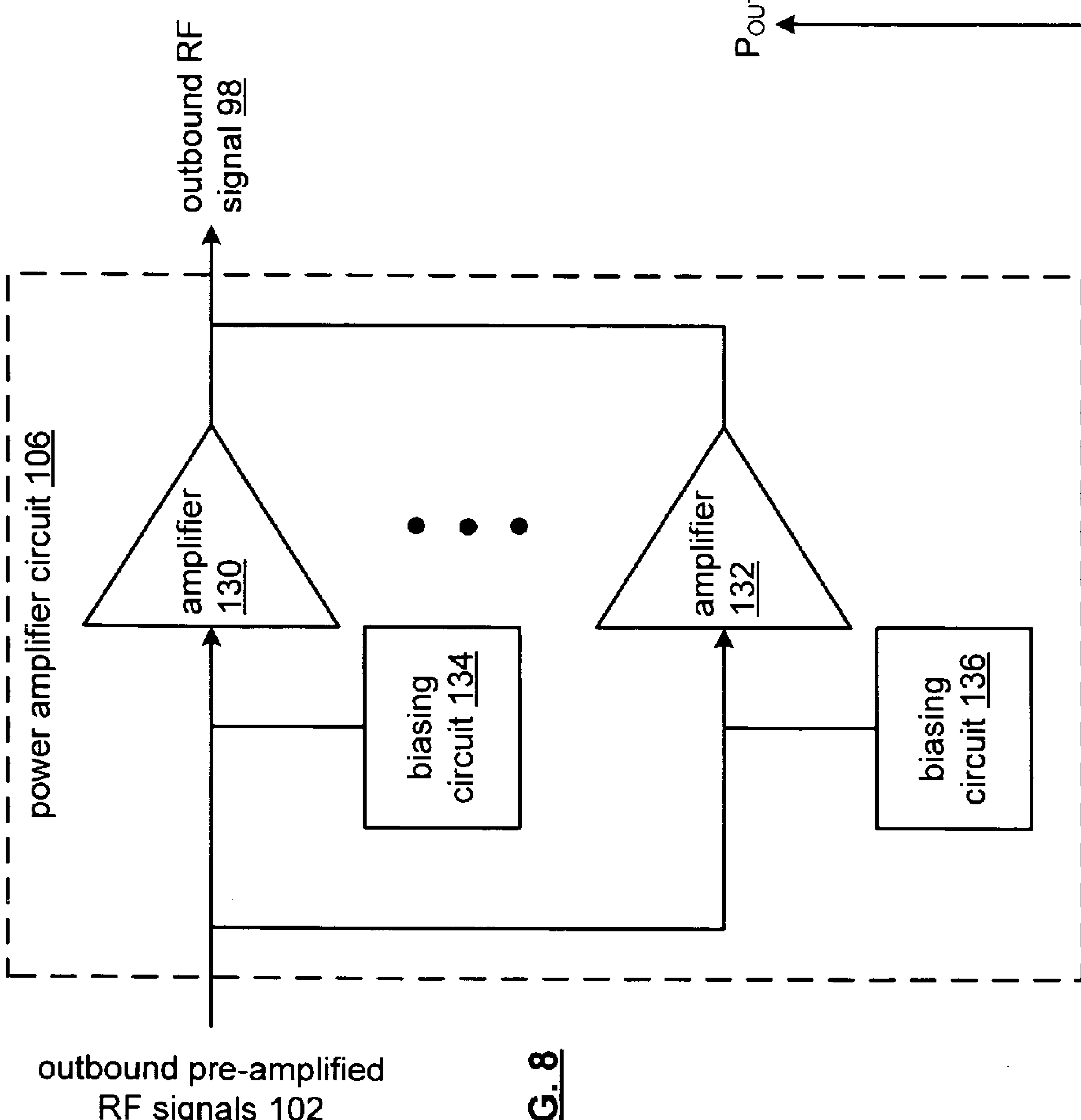

outbound RF signal 98
power amplifier circuit 106
amplifier 130
amplifier 132
biasing circuit 134
biasing circuit 136
outbound pre-amplified RF signals 102

FIG. 8

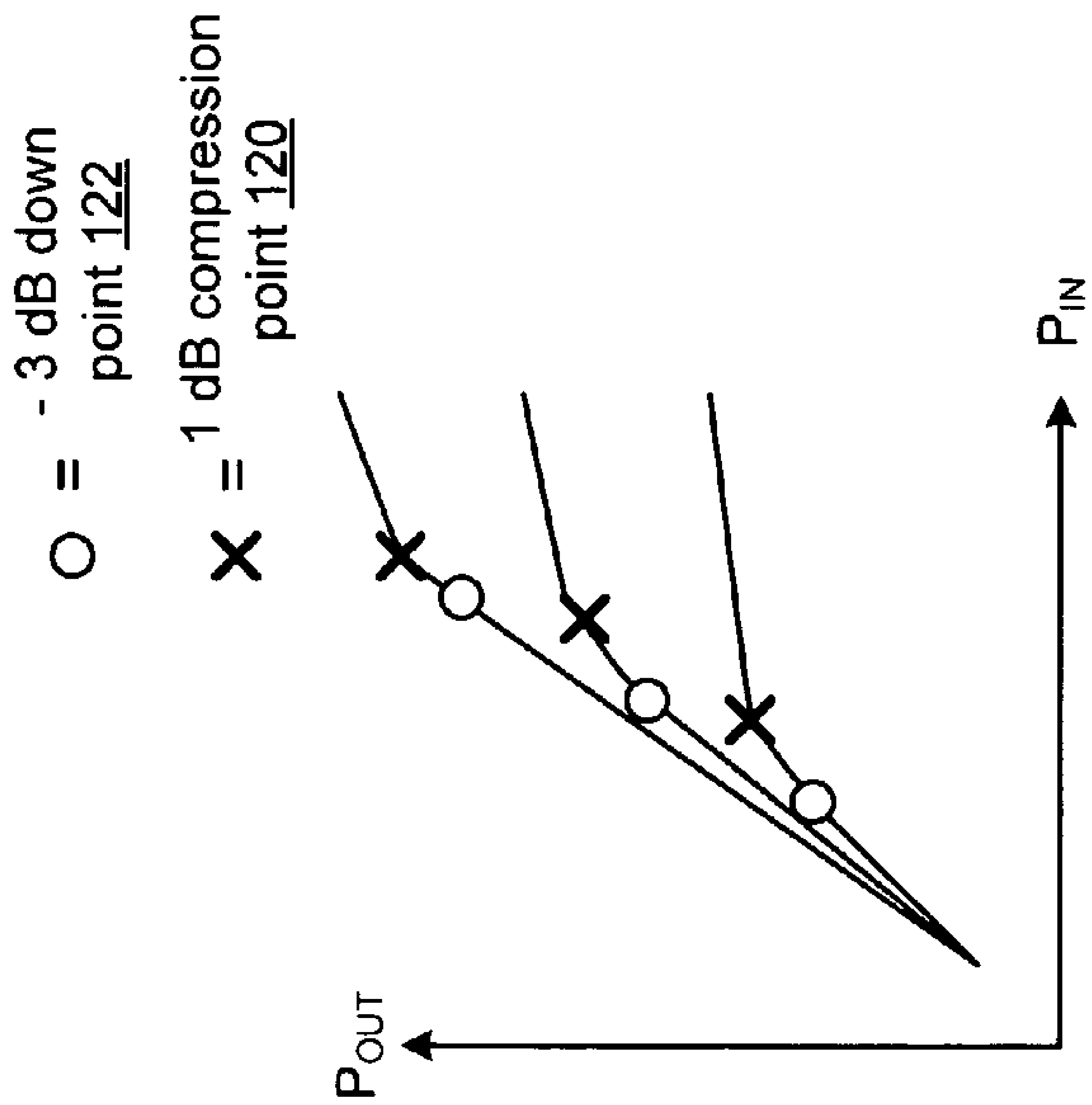

○ = - 3 dB down point 122
✕ = 1 dB compression point 120
$P_{OUT}$
$P_{IN}$

FIG. 9

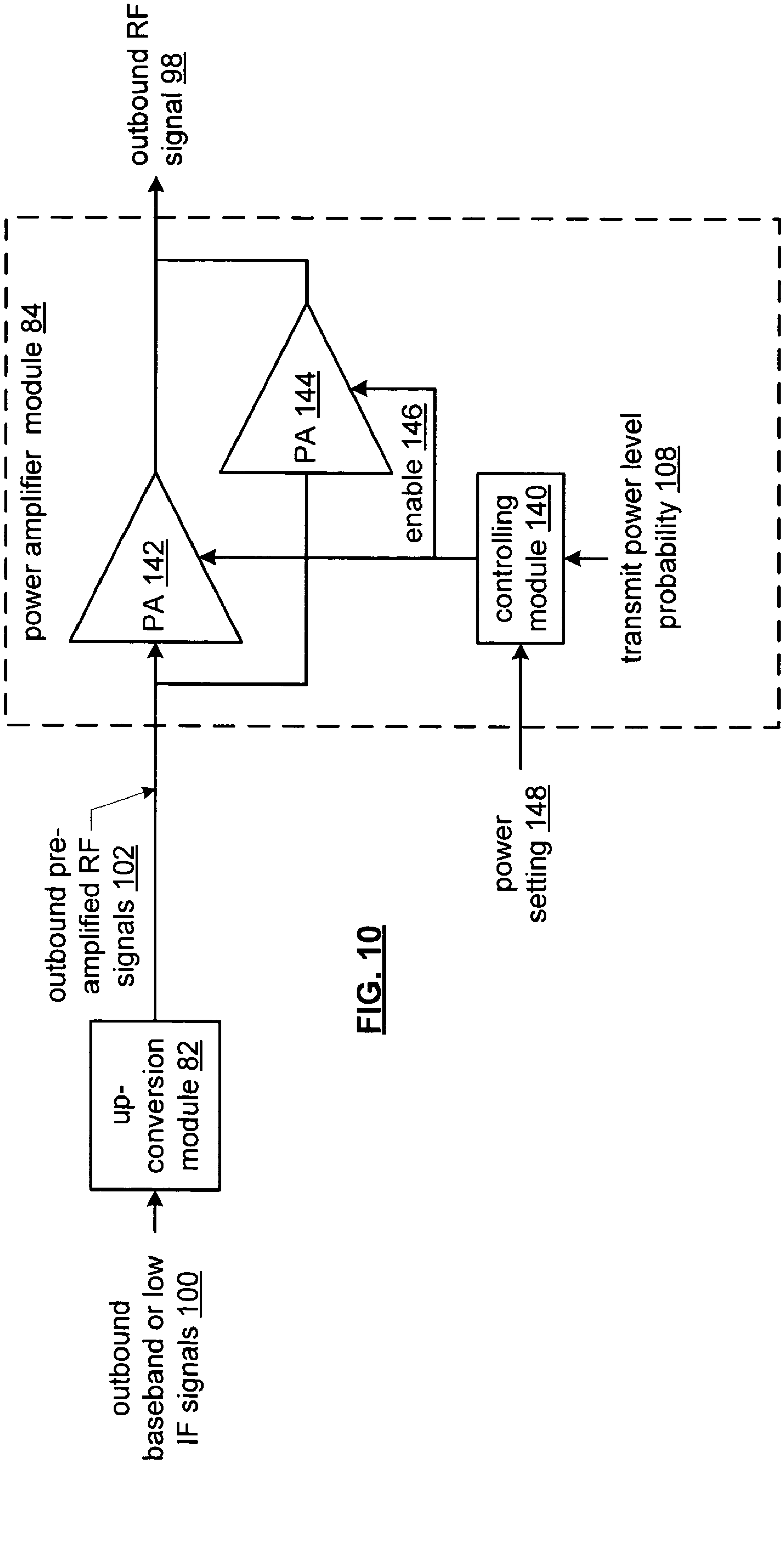

outbound baseband or low IF signals 100
up-conversion module 82
outbound pre-amplified RF signals 102
power amplifier module 84
PA 142
PA 144
enable 146
controlling module 140
transmit power level probability 108
power setting 148
outbound RF signal 98

FIG. 10

# PROBABILITY OPTIMIZED POWER AMPLIFIER MODULE AND TRANSMITTER

## CROSS REFERENCE TO RELATED PATENTS

NOT APPLICABLE

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

NOT APPLICABLE

## INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

NOT APPLICABLE

## BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

This invention relates generally to wireless communication systems and more particularly to transmitters used in such systems.

2. Description of Related Art

Communication systems are known to support wireless and wire lined communications between wireless and/or wire lined communication devices. Such communication systems range from national and/or international cellular telephone systems to the Internet to point-to-point in-home wireless networks. Each type of communication system is constructed, and hence operates, in accordance with one or more communication standards. For instance, wireless communication systems may operate in accordance with one or more standards including, but not limited to, IEEE 802.11, Bluetooth, advanced mobile phone services (AMPS), digital AMPS, global system for mobile communications (GSM), code division multiple access (CDMA), local multi-point distribution systems (LMDS), multi-channel-multi-point distribution systems (MMDS), radio frequency identification (RFID), and/or variations thereof.

Depending on the type of wireless communication system, a wireless communication device, such as a cellular telephone, two-way radio, personal digital assistant (PDA), personal computer (PC), laptop computer, home entertainment equipment, RFID reader, RFID tag, et cetera communicates directly or indirectly with other wireless communication devices. For direct communications (also known as point-to-point communications), the participating wireless communication devices tune their receivers and transmitters to the same channel or channels (e.g., one of the plurality of radio frequency (RF) carriers of the wireless communication system or a particular RF frequency for some systems) and communicate over that channel(s). For indirect wireless communications, each wireless communication device communicates directly with an associated base station (e.g., for cellular services) and/or an associated access point (e.g., for an in-home or in-building wireless network) via an assigned channel. To complete a communication connection between the wireless communication devices, the associated base stations and/or associated access points communicate with each other directly, via a system controller, via the public switch telephone network, via the Internet, and/or via some other wide area network.

For each wireless communication device to participate in wireless communications, it includes a built-in radio transceiver (i.e., receiver and transmitter) or is coupled to an associated radio transceiver (e.g., a station for in-home and/or in-building wireless communication networks, RF modem, etc.). As is known, the receiver is coupled to the antenna and includes a low noise amplifier, one or more intermediate frequency stages, a filtering stage, and a data recovery stage. The low noise amplifier receives inbound RF signals via the antenna and amplifies then. The one or more intermediate frequency stages mix the amplified RF signals with one or more local oscillations to convert the amplified RF signal into baseband signals or intermediate frequency (IF) signals. The filtering stage filters the baseband signals or the IF signals to attenuate unwanted out of band signals to produce filtered signals. The data recovery stage recovers raw data from the filtered signals in accordance with the particular wireless communication standard.



As is also known, the transmitter includes a data modulation stage, one or more intermediate frequency stages, and a power amplifier. The data modulation stage converts raw data into baseband signals in accordance with a particular wireless communication standard. The one or more intermediate frequency stages mix the baseband signals with one or more local oscillations to produce RF signals. The power amplifier amplifies the RF signals prior to transmission via an antenna.

Currently, there are two basic types of RF transmitters: Cartesian based transmitter and a Polar coordinate based transmitter. A Cartesian based transmitter includes baseband processing and RF transmission circuitry. The baseband processing encodes, punctures, maps, interleaves, and domain converts outbound data into an in-phase (I) signal component and a quadrature (Q) signal component. For example, if the baseband processing utilizes a 64 quadrature amplitude modulation (QAM) scheme, an a first outbound data value of 101 may be ½ rate encoded into a value of 11 10 01 and a second outbound data value of 011 may be ½ rate encoded into a value of 00 11 01. After puncturing, the encoded values may be interleaved to produce a first interleaved value of 10 11 01 and a second interleaved value of 01 10 01. The first interleaved value is mapped into an I value of 101 and a Q value of 101 and the second interleaved value is mapped into an I value of 011 and a Q value of 001. Each pair of mapped I and Q interleaved values are converted into time domain signals via an inverse fast Fourier transform (IFFT) for a corresponding sub carrier of the signaling protocol (e.g., orthogonal frequency division multiplexing [OFDM]). The time domain I and Q signals are converted into analog signals via an analog to digital converter to produce the I signal component and the Q signal component.

The RF transmission circuitry includes a local oscillator, a mixing section, a linear power amplifier, and may include RF filtering. For direct conversion transmitters, the local oscillator generates an I local oscillation and a Q local oscillation, which are respectively mixed with the I signal component and the Q signal component via the mixing section. The resulting I mixed signal and Q mixed signal are summed to produce an RF signal. The linear power amplifier amplifies to the RF signal to produce an amplified RF signal that may be subsequently bandpass filtered prior to transmission.

While a Cartesian based RF transmitter provides the advantage of a single side band transmitter (i.e., do not have a negative frequencies with I and Q signals), the transmitter path (i.e., the mixing section and the power amplifier) needs to be linear to avoid loss of data resolution. In particular, the linearity requirement limits the output power of the power amplifier.

A Polar coordinate based transmitter includes baseband processing and RF transmission circuitry. The baseband processing encodes, punctures, maps, interleaves, and domain converts outbound data into polar coordinates of an amplitude

(A) and a phase (Φ). For example, if the baseband processing utilizes a 64 quadrature amplitude modulation (QAM) scheme, an a first outbound data value of 101 may be ½ rate encoded into a value of 11 10 01 and a second outbound data value of 011 may be ½ rate encoded into a value of 00 11 01. After puncturing, the encoded values may be interleaved to produce a first interleaved value of 10 11 01 and a second interleaved value of 01 10 01. The first interleaved value is mapped into an amplitude value of $A_0$ and a phase value of $\Phi_0$ and the second interleaved value is mapped into an amplitude value of $A_1$ and a phase value of $\Phi_1$.

The RF transmission circuitry includes a local oscillator and a power amplifier. The local oscillator includes a phase locked loop (PLL) that generates a local oscillation at a desired RF frequency that is modulated based on phase values $\Phi_0$ and $\Phi_1$. The phase modulated RF signal is then amplitude modulated by the power amplifier in accordance with the amplitude values $A_1$ and $A_1$ to produce a phase and amplitude modulated RF signal.

While the Polar coordinate RF transmitter provides the advantages of reduced RF filtering due to the response of the PLL and the use of a non-linear power amplifier (which, for the same die area, is capable of greater output power than a linear power amplifier), there are some disadvantages. For instance, the response of the PLL is narrow, thus limiting the RF transmitter to narrow band uses. Further, maintaining synchronization between the phase values and the amplitude values can be difficult due to the delays within the PLL. Still further, the baseband processing is utilizing real signals, thus has to account for potential negative frequencies.

From the foregoing, the Cartesian based RF transmitter and Polar based RF transmitter each have their advantages and disadvantages. In addition, both types of transmitters are designed to transmit signals over a wide range of transmit power levels (e.g., from −50 dB to +28 dB) depending on current transmission conditions. While there is a vast range over which the power amplifier of the transmitter may transmit, empirical data has shown that there is a high probability that, for a majority of the time, the power amplifier will transmit at a power level much smaller than the full range (e.g., −25 dB to +15 dB). In addition, a linear power amplifier is most efficient when operating about 3 dB down from its 1 dB compression point.

Therefore, a need exists for a transmitter and power amplifier module that operates efficiently based on transmit power level probability.

## BRIEF SUMMARY OF THE INVENTION

The present invention is directed to apparatus and methods of operation that are further described in the following Brief Description of the Drawings, the Detailed Description of the Invention, and the claims. Other features and advantages of the present invention will become apparent from the following detailed description of the invention made with reference to the accompanying drawings.

## BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

FIG. **1** is a schematic block diagram of a wireless communication system in accordance with the present invention;

FIG. **2** is a schematic block diagram of a wireless communication device in accordance with the present invention;

FIG. **3** is a schematic block diagram of an embodiment of an up-conversion module and a power amplifier module in accordance with the present invention;

FIG. **4** is a graph of an example of a transmit power level probability curve in accordance with the present invention;

FIG. **5** is a schematic block diagram of an embodiment of a power amplifier circuit in accordance with the present invention;

FIG. **6** is a graph of a linear power amplifier in accordance with the present invention;

FIG. **7** is a graph of an example of a transmit power level probability curve and power amplifier operation in accordance with the present invention;

FIG. **8** is a schematic block diagram of another embodiment of a power amplifier circuit in accordance with the present invention;

FIG. **9** is a graph of adjusting performance of a power amplifier in accordance with the present invention; and

FIG. **10** is a schematic block diagram of another embodiment of an up-conversion module and a power amplifier module in accordance with the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** illustrates a schematic block diagram of a communication system **10** that includes a plurality of base stations and/or access points **12-16**, a plurality of wireless communication devices **18-32** and a network hardware component **34**. The wireless communication devices **18-32** may be laptop host computers **18** and **26**, personal digital assistant hosts **20** and **30**, personal computer hosts **24** and **32** and/or cellular telephone hosts **22** and **28**. The details of the wireless communication devices will be described in greater detail with reference to FIG. **2**.

The base stations or access points **12** are operably coupled to the network hardware **34** via local area network connections **36**, **38** and **40**. The network hardware **34**, which may be a router, switch, bridge, modem, system controller, et cetera provides a wide area network connection **42** for the communication system **10**. Each of the base stations or access points **12-16** has an associated antenna or antenna array to communicate with the wireless communication devices in its area. Typically, the wireless communication devices register with a particular base station or access point **12-14** to receive services from the communication system **10**. For direct connections (i.e., point-to-point communications), wireless communication devices communicate directly via an allocated channel.

Typically, base stations are used for cellular telephone systems and like-type systems, while access points are used for in-home or in-building wireless networks. Regardless of the particular type of communication system, each wireless communication device includes a built-in radio and/or is coupled to a radio. The radio includes a highly linear amplifier and/or programmable multi-stage amplifier as disclosed herein to enhance performance, reduce costs, reduce size, and/or enhance broadband applications.

FIG. **2** illustrates a schematic block diagram of a wireless communication device that includes the host device **18-32** and an associated radio **60**. For cellular telephone hosts, the radio **60** is a built-in component. For personal digital assistants hosts, laptop hosts, and/or personal computer hosts, the radio **60** may be built-in or an externally coupled component.

As illustrated, the host device **18-32** includes a processing module **50**, memory **52**, radio interface **54**, input interface **58** and output interface **56**. The processing module **50** and memory **52** execute the corresponding instructions that are typically done by the host device. For example, for a cellular telephone host device, the processing module **50** performs the corresponding communication functions in accordance with a particular cellular telephone standard.

The radio interface **54** allows data to be received from and sent to the radio **60**. For data received from the radio **60** (e.g., inbound data), the radio interface **54** provides the data to the processing module **50** for further processing and/or routing to the output interface **56**. The output interface **56** provides connectivity to an output display device such as a display, monitor, speakers, et cetera such that the received data may be displayed. The radio interface **54** also provides data from the processing module **50** to the radio **60**. The processing module **50** may receive the outbound data from an input device such as a keyboard, keypad, microphone, et cetera via the input interface **58** or generate the data itself. For data received via the input interface **58**, the processing module **50** may perform a corresponding host function on the data and/or route it to the radio **60** via the radio interface **54**.

Radio **60** includes a host interface **62**, digital receiver processing module **64**, analog-to-digital converter **66**, filtering/gain module **68**, down conversion module **70**, low noise amplifier **72**, local oscillation module **74**, memory **75**, digital transmitter processing module **76**, digital-to-analog converter **78**, filtering/gain module **80**, up-conversion module **82**, power amplifier **84**, and an antenna **86**. The antenna **86** may be a single antenna that is shared by the transmit and receive paths or may include separate antennas for the transmit path and receive path. The antenna implementation will depend on the particular standard to which the wireless communication device is compliant. Note that in one embodiment, the up conversion module **82** and power amplifier module **84** may be considered an RF transmitter.

The digital receiver processing module **64** and the digital transmitter processing module **76**, in combination with operational instructions stored in memory **75**, execute digital receiver functions and digital transmitter functions, respectively. The digital receiver functions include, but are not limited to, digital intermediate frequency to baseband conversion, demodulation, constellation demapping, decoding, and/or descrambling. The digital transmitter functions include, but are not limited to, scrambling, encoding, constellation mapping, modulation, and/or digital baseband to IF conversion. The digital receiver and transmitter processing modules **64** and **76** may be implemented using a shared processing device, individual processing devices, or a plurality of processing devices. Such a processing device may be a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on operational instructions. The memory **75** may be a single memory device or a plurality of memory devices. Such a memory device may be a read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, and/or any device that stores digital information. Note that when the processing module **64** and/or **76** implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory storing the corresponding operational instructions is embedded with the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry.

In operation, the radio **60** receives outbound data **94** from the host device via the host interface **62**. The host interface **62** routes the outbound data **94** to the digital transmitter processing module **76**, which processes the outbound data **94** in accordance with a particular wireless communication standard (e.g., IEEE802.11a, IEEE802.11b, Bluetooth, et cetera) to produce digital transmission formatted data **96**. The digital transmission formatted data **96** will be a digital base-band signal or a digital low IF signal, where the low IF will be in the frequency range of zero to a few megahertz.

The digital-to-analog converter **78** converts the digital transmission formatted data **96** from the digital domain to the analog domain. The filtering/gain module **80** filters and/or adjusts the gain of the analog signal prior to providing it to the up-conversion module **82**. The up-conversion module **82** directly converts the analog baseband or low IF signal into an RF signal based on a transmitter local oscillation provided by local oscillation module **74**. The power amplifier **84**, which will be described in greater detail with reference to FIGS. **3**, **5**, **8**, and **10**, amplifies the RF signal to produce outbound RF signal **98**. The antenna **86** transmits the outbound RF signal **98** to a targeted device such as a base station, an access point and/or another wireless communication device.

The radio **60** also receives an inbound RF signal **88** via the antenna **86**, which was transmitted by a base station, an access point, or another wireless communication device. The antenna **86** provides the inbound RF signal **88** to the low noise amplifier **72**, which amplifies the signal **88** to produce an amplified inbound RF signal. The low noise amplifier **72** provide the amplified inbound RF signal to the down conversion module **70**, which directly converts the amplified inbound RF signal into an inbound low IF signal based on a receiver local oscillation provided by local oscillation module **74**. The down conversion module **70** provides the inbound low IF signal to the filtering/gain module **68**, which filters and/or adjusts the gain of the signal before providing it to the analog to digital converter **66**.

The analog-to-digital converter **66** converts the filtered inbound low IF signal from the analog domain to the digital domain to produce digital reception formatted data **90**. The digital receiver processing module **64** decodes, descrambles, demaps, and/or demodulates the digital reception formatted data **90** to recapture inbound data **92** in accordance with the particular wireless communication standard being implemented by radio **60**. The host interface **62** provides the recaptured inbound data **92** to the host device **18-32** via the radio interface **54**.

FIG. **3** is a schematic block diagram of an embodiment of an RF transmitter that includes an up-conversion module **82** and a power amplifier module **84**. The power amplifier module **84** includes a transmit power probability module **104** and a power amplifier circuit **106**. The transmit power probability module **104** is coupled to determine a transmit power level probability **108**. The transmit power probability module **104** may determine the transmit power level probability based on empirical data stored in memory and/or based on a histogram of power level settings of the power amplifier module. For example, as shown in FIG. **4**, the transmit power probability module **104** may determine the power level settings that range from a minimum value to a maximum value. As shown, the curve also includes a most probable range. For example, the minimum value may be −50 dB, the maximum value may be +28 dB, and the most probable range may be −25 dB to +15 dB.

Returning to the discussion of FIG. **3**, the power amplifier circuit **106**, which may include one or more power amplifiers and/or pre-amplifiers as will be discussed in greater detail with reference to FIGS. **5**, **8**, and **10**, is coupled to amplify an outbound radio frequency (RF) signal at a power level in accordance with the transmit power level probability **108** and a desired transmit power level. The power amplifier circuit **106** is optimized based on the transmit power level probability **108** to amplify the outbound RF signal **102** at the desired transmit power level. As such, for a majority of the time, the power amplifier circuit **106** is operating at or near its most efficient point and operates at less efficient points for transmit power levels that are outside of the most probable range. However, since the less efficient operation occurs much less than the optimal efficiency operation, the overall efficiency of the power amplifier is improved.

FIG. **5** is a schematic block diagram of an embodiment of a power amplifier circuit **106** that includes a plurality of power amplifiers **110** and **112**. The power amplifiers **110** and **112** are operable in accordance with the transmit power level probability **108** to provide the desired transmit power level of the outbound pre-amplifier RF signals **102** to produce the outbound RF signals **98**. For instance, each of the power amplifiers **110** and **112**, when in a linear mode, have a power input to power output curve as shown in FIG. **6**.

In FIG. **6**, the power amplifier **110-112** is substantially linear up to its 1 dB compression point **120**. Further, the power amplifiers **110** and **112** are most efficient at the −3 dB down point **122** from the 1 dB compression point **120**. As, for the most probable power levels, it is desirous to have the power amplifiers **110** and **112** operating at or near the −3 dB down point **122**. An example of this is shown in FIG. **7**.

FIG. **7** is a graph of an example of a transmit power level probability curve and power amplifier **110-112** operation. In this example, the most probable range of the transmit power level probability curve is divided into three sections. In the first section, power amplifier **110** is on and power amplifier **112** is off. For this section, the power amplifier **110** is configured (i.e., gain setting, bias setting, supply voltage setting, etc.) to provide optimum efficiency. In the second section, power amplifier **112** is on and power amplifier **110** is off. For this section, the power amplifier **112** is configured (i.e., gain setting, bias setting, supply voltage setting, etc.) to provide optimum efficiency. In the third section, both power amplifiers **110** and **112** are on and configured to provide optimum efficiency. As one of ordinary skill in the art will appreciate, the power amplifier circuit **106** may include more than two power amplifiers and that each power amplifier may have the same power amplification capabilities and/or different power amplification capabilities.

In an embodiment, when the desired transmit power level exceeds a threshold of where the power amplifier circuit **106** is optimally efficient in a linear mode, the radio **60** may change from having a Cartesian based RF transmitter to a Polar based RF transmitter. In the Polar based RF transmitter, the power amplifier circuit **106** does not need to be linear, thus it can run at power levels above the 1 dB compression point efficiently and without loss of information.

FIG. **8** is a schematic block diagram of another embodiment of a power amplifier circuit **106** that includes a plurality of amplifiers **130-132** and a plurality of biasing circuits **134-136**. The plurality of amplifiers **130-132** amplify the outbound pre-amplified RF signals **102** to produce the outbound RF signals **98** in accordance with the biasing provided by the biasing circuits **134-136**.

The biasing circuits **134-136** adjust the biasing of the power amplifiers **130-132** based on the transmit power level probability **108** and the desired transmit power level such that the operating point of the power amplifiers **130-132** is optimized for the desired transmit power level. FIG. **9** is a graph illustrates the adjusting the power amplifier in **130-132** operating point. The three curves represent different biasing levels for the power amplifier **130-132**. On each of the curves, the circle represents the −3 dB down point **122** and the X represents the 1 dB compression point **120**. As such, a power amplifier may be designed to have the properties shown in FIG. **9** for a given region of the most probable range of the probability curve. Thus, when the desired transmit power level is with the given region, the power amplifier may be adjusted to provide optimal efficiency for the desired transmit power level.

FIG. **10** is a schematic block diagram of another embodiment of an RF transmitter that includes the up-conversion module **82** and the power amplifier module **84**. In this embodiment, the power amplifier module **84** includes first and second power amplifiers **142** and **144** and a controlling module **140**.

In operation, the up-conversion module **82** converts the outbound baseband or low IF signals **100** into outbound pre-amplified RF signals **102**. The first power amplifier **142** has its amplification (e.g., gain setting, supply voltage, biasing level, etc.) set for optimal efficiency in accordance with most probable transmit power level settings within a transmit power level range to amplify the outbound pre-amplified RF signal when enabled. The second power amplifier **144** has its amplification set for optimal efficiency in accordance with the most probable transmit power level settings within the transmit power level range to amplify the outbound pre-amplified RF signal when enabled.

The controlling module **140** enables **146** one of the first and second power amplifiers **142** and **144** to amplify the outbound RF signal **102** in accordance with a power setting **148** when the power setting is not within the most probable transmit power level settings. The controlling module **140** enables **146** at least one of the first and second power amplifiers **142** and **144** to amplify the outbound RF signal **102** in accordance with the power setting **148** when the power setting is within the most probable transmit power level settings of a transmit power level probability **108**.

In an embodiment, the controlling module **140** enables **146** the first power amplifier **142** to amplify the outbound RF signal in accordance with the power setting **148** when the power setting is within a first range of the most probable transmit power level settings. Note that the power amplifier **142** is optimized for performance within the first range of the most probable transmit power level settings. Further note that the optimal performance may be fixed within the first range or adjustable by adjusting one or more of the biasing, gain setting, supply voltage, etc. In this embodiment, the controlling module **140** enables **146** the first and second power amplifiers **142** and **144** to amplify the outbound RF signal **102** in accordance with the power setting **148** when the power setting is within a second range of the most probable transmit power level settings. In this instance, the first and second power amplifiers **142** and **144** are optimized for performance within the second range.

In another embodiment, the controlling module **140** determines a first bias adjust indication based on the power setting **148** and the first range of the most probable transmit power level settings. The controlling module **140** then provides the first bias adjust indication to the first power amplifier **142** such that the first power amplifier **142** adjusts its biasing in accordance with the first bias adjust indication to maintain the amplification for optimal efficiency.

In another embodiment or as an extension of the preceding embodiment, the controlling module **140** determines a second bias adjust indication based on the power setting **148** and the second range of the most probable transmit power level settings. The controlling module **140** then provides the second bias adjust indication to the second power amplifier **144** such that the second power amplifier **144** adjusts its biasing in accordance with the second bias adjust indication to maintain the amplification for optimal efficiency. Note that the providing the biasing indication to the power amplifiers **142** and **144** may be done with the connection to enable the amplifiers.

In another embodiment, the controlling module **140**, which may be a separate processing module and/or included in the digital receiver and/or transmit processing module **64** and **76**, enables the first power amplifier **142** to amplify the outbound RF signal **102** in accordance with the power setting **148** when the power setting is within a first range of the most probable transmit power level settings. Further, the controlling module **140** enables the second power amplifier **144** to amplify the outbound RF signal **102** in accordance with the power setting **148** when the power setting is within a second range of the most probable transmit power level settings. Still further, the controlling module **140** enables the first and second power amplifiers **142** and **144** to amplify the outbound RF signal **102** in accordance with the power setting **148** when the power setting is within a third range of the most probable transmit power level settings.

In another embodiment, the power amplifier module **84** further comprises a third power amplifier having its amplification set for optimal efficiency in accordance with the most probable transmit power level settings within the transmit power level range. In this embodiment, the controlling module enables one of the first, second, and third power amplifiers to amplify the outbound RF signal in accordance with a power setting **148** when the power setting is not within the most probable transmit power level settings. The controlling module **140** enables at least one of the first, second, and third power amplifiers to amplify the outbound RF signal in accordance with the power setting when the power setting is within the most probable transmit power level settings.

In yet another embodiment, the controlling module enables one of the first and second power amplifiers **142** and **144** to amplify the outbound RF signal in accordance with the power setting **148** when the power setting is a low power low probability setting that is not within the most probable transmit power level settings. The controlling module **140** provides an indication to the first and second power amplifiers to adjust biasing for a substantially maximum transmit power level and enables the first and second power amplifiers to amplify the outbound RF signal in accordance with the power setting when the power setting is a high power low probability setting that is not within the most probable transmit power level settings.

As may be used herein, the terms “substantially” and “approximately” provides an industry-accepted tolerance for its corresponding term and/or relativity between items. Such an industry-accepted tolerance ranges from less than one percent to fifty percent and corresponds to, but is not limited to, component values, integrated circuit process variations, temperature variations, rise and fall times, and/or thermal noise. Such relativity between items ranges from a difference of a few percent to magnitude differences. As may also be used herein, the term(s) “coupled to” and/or “coupling” and/or includes direct coupling between items and/or indirect coupling between items via an intervening item (e.g., an item includes, but is not limited to, a component, an element, a circuit, and/or a module) where, for indirect coupling, the intervening item does not modify the information of a signal but may adjust its current level, voltage level, and/or power level. As may further be used herein, inferred coupling (i.e., where one element is coupled to another element by inference) includes direct and indirect coupling between two items in the same manner as “coupled to”. As may even further be used herein, the term “operable to” indicates that an item includes one or more of power connections, input(s), output (s),etc., to perform one or more its corresponding functions and may further include inferred coupling to one or more other items. As may still further be used herein, the term “associated with”, includes direct and/or indirect coupling of separate items and/or one item being embedded within another item. As may be used herein, the term “compares favorably”, indicates that a comparison between two or more items, signals, etc., provides a desired relationship. For example, when the desired relationship is that signal **1** has a greater magnitude than signal **2**, a favorable comparison may be achieved when the magnitude of signal **1** is greater than that of signal **2** or when the magnitude of signal **2** is less than that of signal **1**.

The present invention has also been described above with the aid of method steps illustrating the performance of specified functions and relationships thereof. The boundaries and sequence of these functional building blocks and method steps have been arbitrarily defined herein for convenience of description. Alternate boundaries and sequences can be defined so long as the specified functions and relationships are appropriately performed. Any such alternate boundaries or sequences are thus within the scope and spirit of the claimed invention.

The present invention has been described above with the aid of functional building blocks illustrating the performance of certain significant functions. The boundaries of these functional building blocks have been arbitrarily defined for convenience of description. Alternate boundaries could be defined as long as the certain significant functions are appropriately performed. Similarly, flow diagram blocks may also have been arbitrarily defined herein to illustrate certain significant functionality. To the extent used, the flow diagram block boundaries and sequence could have been defined otherwise and still perform the certain significant functionality. Such alternate definitions of both functional building blocks and flow diagram blocks and sequences are thus within the scope and spirit of the claimed invention. One of average skill in the art will also recognize that the functional building blocks, and other illustrative blocks, modules and components herein, can be implemented as illustrated or by discrete components, application specific integrated circuits, processors executing appropriate software and the like or any combination thereof.

What is claimed is:

**1**. A power amplifier module comprising:

a transmit power probability module coupled to determine a transmit power level probability;

a power amplifier circuit coupled to amplify an outbound radio frequency (RF) signal at a power level in accordance with the transmit power level probability and a desired transmit power level, the power amplifier circuit includes a plurality of selectable power amplifiers, wherein at least one of the plurality of selectable power amplifiers is enabled based on the transmit power level probability and the desired transmit power level to amplify the outbound RF signal at the desired transmit power level; and

an adjustable biasing circuit coupled to adjust biasing of the at least one of the plurality of selectable power amplifiers based on the desired transmit power level to maintain optimal efficiency in accordance with a corresponding most probable power level of the transmit power level probability.

**2**. The power amplifier module of claim **1**, wherein the transmit power probability module determines the transmit power level probability based on empirical data stored in a memory.

**3**. The power amplifier module of claim **1**, wherein the transmit power probability module determines the transmit power level probability based on a histogram of power level settings of the power amplifier module.

**4**. A radio frequency (RF) transmitter comprising:

an up-conversion module coupled to convert an outbound baseband or low intermediate frequency (IF) signal into an outbound radio frequency (RF) signal; and

a power amplifier module that includes:

a transmit power probability module coupled to determine a transmit power level probability;

a power amplifier circuit coupled to amplify the outbound RF signal at a power level in accordance with the transmit power level probability and a desired transmit power level, the power amplifier circuit includes a plurality of selectable power amplifiers, wherein at least one of the plurality of selectable power amplifiers is enabled based on the transmit power level probability and the desired transmit power level to amplify the outbound RF signal at the desired transmit power level; and

an adjustable biasing circuit coupled to adjust biasing of the at least one of the plurality of selectable power amplifiers based on the desired transmit power level to maintain optimal efficiency in accordance with a corresponding most probable power level of the transmit power level probability.

**5**. The RF transmitter of claim **4**, wherein the transmit power probability module determines the transmit power level probability based on empirical data stored in memory.

**6**. The RF transmitter of claim **4**, wherein the transmit power probability module determines the transmit power level probability based on a histogram of power level settings of the power amplifier module.

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